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A METHOD OF ESTIMATING BEET LEAFHOPPER POPULATIONS FROM THE PROPORTION OF UNINFESTED PLANTS 1/

By M. F. Bowen, 2/
Division of Truck Crop and Garden Insect Investigations

In the course of ecological studies of the beet leafhopper (Eutettix tenellus (Bak.)), a large number of population counts were taken in beet fields within the range of this insect. The purpose of these counts was to determine the time and magnitude of the spring movement from the breeding areas to the beet fields, and also to follow the trend of populations during the period of the spring movement.

Statistical analyses of these data demonstrated that the populations that move into the beet fields are distributed in a Poisson series. This indicated that the mean number of leafhoppers per plant can be estimated from the proportion of plants not infested, or from the portion of plants infested with a given number of the insects. Since it appeared that this method might be more rapid than the conventional method, a study was made of its reliability and its practical application.

Theoretical Considerations.

In a Poisson distribution the mean determines the frequency of occurrence of a given number of individuals in the sampling units. In other words, the mean may be calculated from the proportion of the total number of sampling units of a given class, that is, from the proportion of sampling units in which a given number of individuals are found. For example, if beet leafhoppers are distributed in a Poisson distribution and 37 percent of the plants are not

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1/ This paper was read at the joint meetings of the American Association of Economic Entomologists and the Entomological Society of America at San Francisco, Calif., Dec. 29, 1941, to Jan. 1, 1942.

2/ Now with the Ninth Service Command, Army Service Forces.

infested, then it is possible to equate the mean of the distribution from the equation $e^{-m} = 0.37$. The mean is 1 leafhopper per plant. This relation between the mean and the proportion of 0's is shown graphically by curve A in figure 1. Curves B, C, and D in this figure show the relation between the mean and the proportion of 1's, 2's, and 3's, respectively. The values shown in the curves may be obtained by direct calculations or from tables prepared by Pearson 3/

The curves for all except the proportion of 0's have two values of the mean corresponding to every relative frequency. For this reason classes greater than 0 must be used with caution. For example, if the percentage of 1's is used and this number appears in 20 percent of the sampling units, it may indicate a mean of either 0.25 or 2.53 insects per unit area. Similar difficulties in determining mean values will appear when the 2's, 3's, or higher numbers are used. Therefore, the relative frequency of classes higher than 0 can safely be employed only when the mean is approximately known, and preferably when it is equal to or greater than the size of the class being used.

Theoretically, the mean will be estimated from a class frequency with the least absolute error by using the class having the greatest relative frequency. The error of estimation increases rapidly with departure from this maximal value. It can be shown by methods of the calculus that for a Poisson distribution any class frequency will be at a maximum when the mean is equal to the size of the class. This fact is graphically illustrated by the curves in figure 1, which indicate maxima of 0's, 1's, 2's, or 3's when the means are, respectively, 0.0, 1.0, 2.0, or 3.0.

Practical Application

The application of frequencies of higher-than-0 classes in estimating beet leafhopper populations is of doubtful utility. Since the insect is small and very active, the effort required to determine the proportion of samples infested with 1, 2, or a higher number of leafhoppers becomes almost as great as to make a complete census of the sample units. This difficulty becomes increasingly pronounced as the size of the class is increased. On the other hand, the mere presence or absence of the insect may be determined with speed and

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3/ Pearson, K. Tables for statisticians and biometricians. Pt. 1, ed. 3, table 51, pp. 113-121. 1930.

accuracy, and a large number of samples may be taken in a short time.

Data obtained in the Grand Valley area of Colorado in the spring and early summer of 1937 are used here to illustrate the application of the percentage-frequency method to the estimation of populations of the beet leafhopper. The data are summarized in figure 2. Each date mean plotted in figure 2 represents the average of the means obtained from 10 fields scattered over the area. The mean for each field on each date was based on 50 sampling units.

Clearly there is a striking agreement between the mean populations per beet calculated by the two methods. This agreement supports the conclusion that migrant beet leafhoppers are distributed in a Poisson series, inasmuch as the calculated values were obtained by a formula derived from this series.

The large increases from June 21 to 28 and June 28 to July 15 represent the beginning of the appearance of adults of the first summer generation. The leafhopper population estimated by the two methods agrees very closely but the calculated values tend to be slightly lower than the observed. The correlation coefficient for the 15 pairs of means is $r = 0.994$, which denotes a high degree of association between the two sets of values.

Conclusions

The foregoing data demonstrate that the proportion of uninfested plants may be used to estimate the density of migrant beet leafhopper populations. However, the method has limitations, of which the following should be noted:

(1) It is applicable only when the distribution of the insect accords with the Poisson law. As the distribution deviates from this law there will be an increased tendency for the method to underestimate the true population.

(2) The mean determined from the proportion of 0's will be estimated with less precision than that obtained from the total sample, but the larger number of sampling units that may be taken compensates for this deficiency, at least within certain ranges of population density.

(3) The method is adapted primarily to populations of low density, say between 0 and 3.00 insects per unit area. For a Poisson distribution with a mean of 5.00, 0's will appear only about 7 times

in 1,000 samples; and for a mean of 7.00 only once in 1,000 samples. Obviously such small probabilities render impracticable the use of the 0 class in estimating dense populations because of the large number of sampling units that would be required. When dense populations are studied, perhaps equal information could be obtained with less effort by taking a smaller number of sampling units and estimating the mean in the usual manner. This is a point that requires further study.

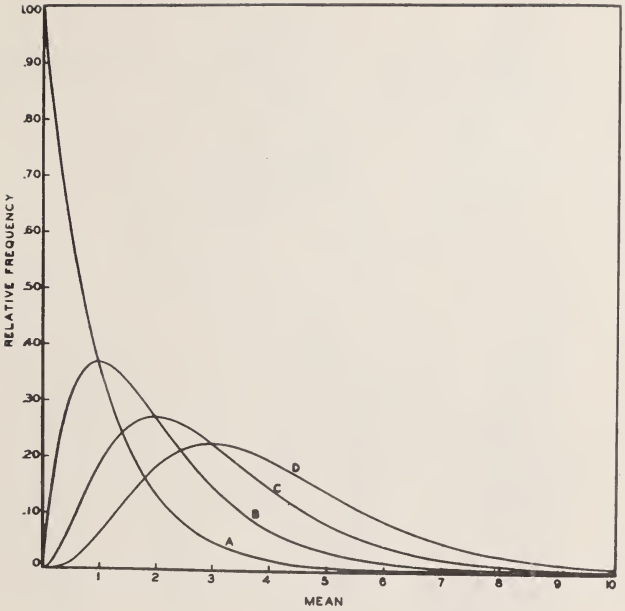

Figure 1.--Relation between the mean in a Poisson distribution and the relative frequency of 0's (curve A), of 1's (curve B), of 2's (curve C), and of 3's (curve D).

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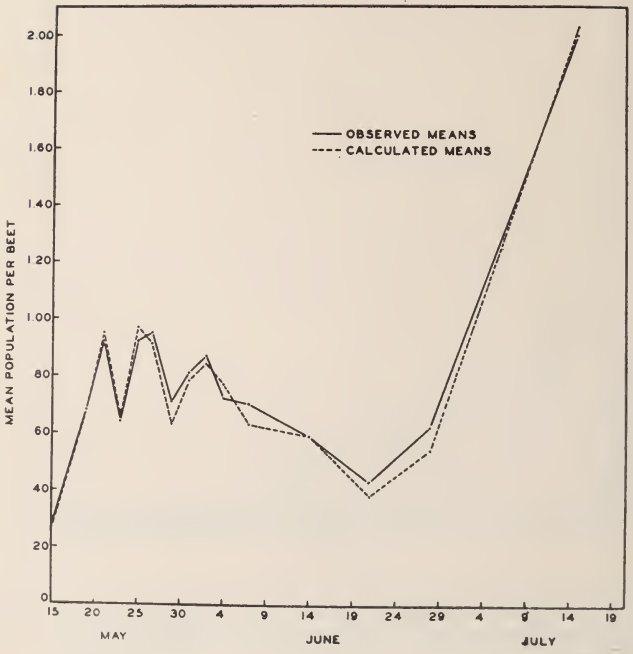

Figure 2.--Populations of the beet leafhopper on sugar beets in the Grand Valley area of Colorado in the spring and early summer of 1937. Observed means are shown by the solid line, and the means calculated from the relative frequency of the 0 class by the broken line.